



SQUAD: A Tool for Spatial Quality and Anomalies Diagnosis

Documentation and Tutorial
QGIS Version

May 2018

MS-18-132



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John Spencer and Becky Wilkes of MEASURE Evaluation, University of North Carolina at Chapel Hill, wrote the original tool for ArcGIS; they collaborated with André Williams, independent consultant, to write the QGIS version of the tool.

CONTENTS

Acknowledgments.....	iii
Abbreviations.....	v
Background.....	1
The Need for the Tool and the Logic Behind It.....	1
Scenario.....	2
What You Will Need	2
SQUAD Tool Tutorial.....	4
Setting up a Project File in QGIS.....	4
Installing and Running the Plug-In	5
Familiarizing Yourself with the Data	6
Running the Tool	7
Observing the Results.....	10
Data Correction Process.....	13
Anomaly 1. Missing coordinates.....	13
Anomaly 2. Truncated coordinates (lack of adequate precision).....	13
Anomaly 3. Duplicate coordinates for distinct records	13
Anomaly 4. Duplicate key attributes	14
Anomaly 5. Coordinate not located where expected, but falling within two kilometers of a border.....	14
Anomaly 6. Coordinate not located anywhere near where expected.....	14
Conclusion	15
Appendix A. Creating a Point File from a List of Coordinates.....	16
Appendix B. Coordinate Systems and Projections.....	18

ABBREVIATIONS

CSV	comma-separated values
GIS	geographic information system
GPS	Global Positioning System
SQUAD	Spatial Quality and Anomalies Diagnosis
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

BACKGROUND

The Need for the Tool and the Logic Behind It

Data are essential to a well-functioning health system. An explosion in the quantity of data available has prompted an increasing emphasis on how this information can be used to advance global health. Within this burgeoning “data tsunami,” as some have called it, are rich streams of data on the populations at risk and in need of treatment for HIV and other diseases, the services being provided, and the context in which these both exist. Many of these data streams have a geographic component. We know more about “where things are” than ever before. Knowing where a health clinic or dispensary is located can be useful in making decisions about how best to provide public health services for a certain size or type of population or how to handle referrals from nearby facilities.

The amount of data it is now possible to comprehend within a health information system presents both a challenge and an opportunity to improve health and health services in low- and middle-income countries. MEASURE Evaluation, funded by the United States Agency for International Development (USAID), takes a holistic view of health information systems. That means we help countries improve and digitize their health information, but we also help build human capacity to understand and manage the rich data now available. Spatial data is an important part of this holistic view.

These kinds of geographic data coordinates are easier than ever to collect, by using a smartphone, tablet, or Global Positioning System (GPS) receiver. When the coordinates are stored in a table or spreadsheet, they can be shown on a map.

One way to ensure that the coordinates are accurate is to plot the locations in a geographic information system (GIS) and then carefully examine the attribute data associated with the points. The data table can be quite large, involving many hundreds or thousands of points. Reviewing each point location for accuracy and correctness in such a large database can be time-consuming, tedious, and challenging because of the complex relationship between the spatial characteristics and the associated attributes of the data points. Ensuring geographic data quality typically requires the skills of an experienced GIS technician.

The Spatial Quality and Anomalies Diagnosis (SQUAD) tool provides a framework for assessing the overall quality of a spatial database and can be run by someone with minimal GIS experience. The tool provides a consistent, clear assessment of potential problems with a given spatial database. After potential anomalies

The Value of This Manual

Why useful: Large spatial data sets can be used to locate disease hot spots or health facilities where services are needed. However, these data can be difficult to check for quality without a time-consuming examination by a trained GIS technician. This new tool—called the Spatial Quality and Anomalies Diagnosis (SQUAD) Tool (<https://www.measureevaluation.org/resources/tools/geographic-information-systems/squad-tool>)—can help a GIS novice identify potential errors in a location-based data set (such as a master facility list) in a short period. This document proposes data correction strategies, based on the tool's output.

Advantage of QGIS version: Traditionally, the use of a full-featured GIS requires an expensive license. However, the blooming of open-source software has brought with it a full-featured GIS software that is free and open-source, called QGIS. The SQUAD tool is now available as a QGIS plug-in. This document shows how to get the software and how to install the plug-in.

have been identified, the records in question can then be examined in detail, and the errors can be corrected. This tool offers a clear picture of the extent and type of the problems that might be associated with a given geographic data set, enabling solutions for improving the data to be prioritized.

The tool checks for six anomalies that are based on common errors in point-location data sets. This information can be used to prioritize the type and extent of investigation needed for records that may have problems. The tool checks for the following anomalies:

1. Missing coordinates
2. Truncated coordinates (lack of adequate precision)
3. Duplicate coordinates for distinct records
4. Duplicate key attributes (two identical names, but plotting in different locations)
5. Coordinate not located exactly where it would be expected (but falling within two kilometers of a border)
6. Coordinate not located anywhere near where expected

The presence of some anomalies may not mean that there are errors. For example, two different sites in two different districts could have the same name but would be reported as an anomaly. These kinds of anomalies merit examination to ensure that they are not errors.

Although additional data quality assessment will likely be required, this framework is a starting point for examining a large data set in an efficient manner. If these errors are identified early, the data set can be corrected and made stronger, more useful, and more trustworthy.

The sections that follow describe a practice session with the tool.

Scenario

Your health ministry has done extensive data collection to locate every health facility in the country. The data, in the form of facility names, districts, and GPS coordinates, must now be checked for quality assurance.

You need a quick but systematic way to determine whether each facility is located in its expected location on the country district map, and if not, why not. By getting a look at the scope of potential problems in this new data set, you can plan how to fix them. A high-quality data set will boost confidence and ensure maximum utility in the future.

What You Will Need

The SQUAD tool is available as a plug-in for QGIS that runs using the data in question. It requires QGIS version 2.18 or 3.0, which is available for free use and distribution without license from www.qgis.org. The facility point file (containing the facility's X and Y coordinates and attributes) and the associated administrative unit file (with names and outlines of districts or regions) must both be stored as shapefiles. These commonly used GIS files store both geometry information (points, lines, and area locations) and attribute information (names and other characteristics of things at each location). See **Appendix A** for what to do if your X and Y coordinates are stored in a spreadsheet and need to be plotted to a point file.

These files can be stored either in WGS84 (World Geodetic System 1984) unprojected format or in an appropriate UTM (Universal Transverse Mercator) projection (so that measurements can be made in meters). More information about coordinates and projections is available in **Appendix B**.

The following are required for each shapefile's attribute data table:

- Facility (point) shapefile should include the following:
 - Unique ID: a unique identifier for a facility
 - Separate fields for the X (longitude) and Y (latitude) coordinates of the site (in decimal degrees)
 - Site name: name of the site or facility
 - Admin: name of the administrative unit where the site is located
- District (polygon) shapefile should include the following:
 - A field with a name for the administrative unit (such as a district name)
 - An ID field for each administrative unit

To go through the tutorial described in the SQUAD Tool Tutorial Section, you will need to download the [sample data](#) provided on [the MEASURE Evaluation website](#) with the QGIS Quick Start Guide. The data contain two shapefiles: one representing all the facility point locations and another that contains the boundaries and names for all associated districts in a theoretical country (available at <https://www.measureevaluation.org/resources/tools/geographic-information-systems/squad-tool/qgis%20sample%20data%20package.zip> or use <http://bit.ly/sampleSQUAD>).


SQUAD TOOL TUTORIAL

Setting up a Project File in QGIS

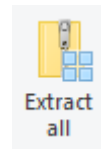
NOTE: Screen shots are for QGIS version 2.18. The interface of version 3.0 may have a slightly different appearance, but the steps are basically the same.

Step 1

Copy the sample data file to the location of your choice.

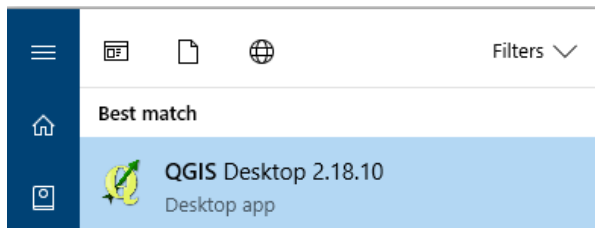
 **sample data.zip**

Double-click on the file and choose **Extract all**.

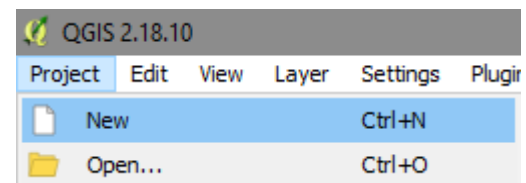


Step 2

Launch QGIS by clicking on the QGIS Desktop shortcut icon or by searching for the app in the windows taskbar and clicking on it.



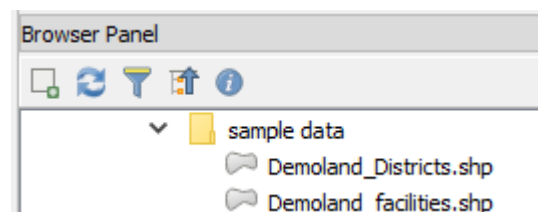
Open a new project by selecting **Project>New**.



Step 3

In the Browser Panel, **navigate** to your sample data folder.

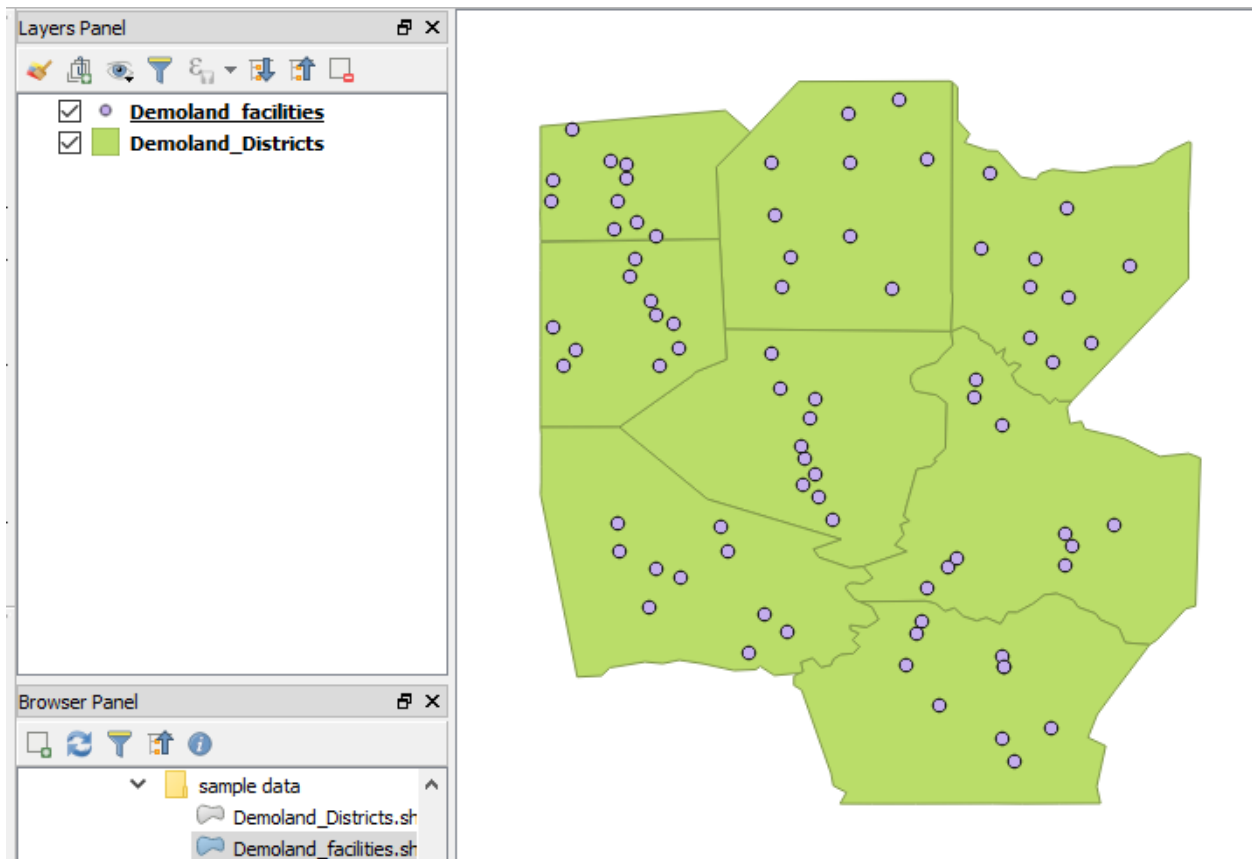
NOTE: If you do not see a Browser Panel, choose View>Panels>Browser Panel.



Double-click on the **Demoland_Districts.shp** file and the **Demoland_facilities.shp** file to load them in the main view panel. The file names will appear in the Layers Panel.

NOTE: Colors will be chosen automatically. To customize the colors, double-click on each symbol in the Layers Panel to open the Layer Properties box. Select the Style or Symbology tab and change the fill color. If the facilities file was loaded first, drag the file name to the top of the Layers Panel to see it on the map.

Your screen should look like the following:



NOTE: If you do not see these Panels, go to View>Panels>.

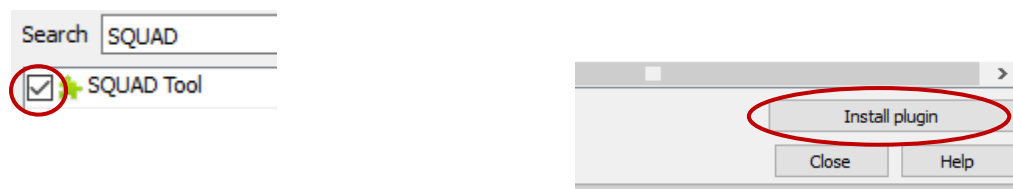
If you would like to **Save** the file and come back to it, you may now do so. The saved file will have the extension “**.qps,**” which stands for “QGIS project file.”

NOTE: A “project file” is a **reference** to a set of GIS data files, such as shapefiles, and serves as a work place where you can view the data files and assign them various styles. The Demoland_Districts file is symbolized by polygons because it represents areas. The Demoland_facilities file is symbolized by points because it represents discrete locations. **The data do not reside in the project file; they reside in the shapefiles.** If you want to share a project file, you should also share the shapefiles that it references.

Installing and Running the Plug-In

Go to **Plugins>Manage and Install Plugins...**

In the Search bar, type “SQUAD” and **type** “Enter.” In the results box, you should see “SQUAD Tool” (for version 3.0, look for “SQUAD Tool v3”). **Check** the box next to it, and then **click on** the “Install plugin” button in the lower right.



Close the dialog box, and the tool's icon will appear in  your toolbar.

You can also access the installed tool via **Plugins>SQUAD>SQUAD Plugin**.

Familiarizing Yourself with the Data

Step 1

Right-click on the Demoland_facilities layer in the Layers Panel and select “Open Attribute Table.” This will open a table listing the fields that house the attribute data associated with these data points.

Demoland_facilities :: Features total: 80, filtered: 80, selected: 0

	NAME	Region	Country	POINT_X	POINT_Y	District	UID
1	Robin	Animal	Demoland	-44.89533611730	30.86118355340	Bird	dc6cba704964
2	Hawk	Animal	Demoland	-45.01422905090	30.81785074000	Bird	437ef5aa687a
3	Pigeon	Animal	Demoland	-44.70000000000	31.13618070930	Bird	8e52d1290c31
4	Woodpecker	Animal	Demoland	-44.74283078150	31.00000000000	Bird	4c2c62e984ee
5	Crow	Animal	Demoland	-45.04645066750	30.90451645490		7c55d0a02f16
6	Parrot	Animall	Demoland	-44.81005638280	30.75396183680	Bird	60bd9e0f0e34

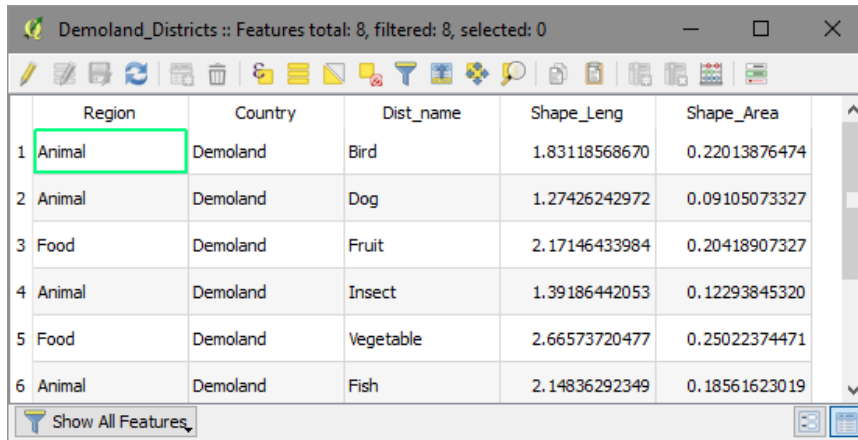
Show All Features

The fields are described as follows:

- **Name** is the name of each facility.
- **Region, Country, and District** help indicate the position of each facility. In this example, the SQUAD tool will determine whether the District records are correct.
- **POINT_X** is the longitude coordinate in decimal degrees. (It is negative because it is located west of the prime meridian.)
- **POINT_Y** is the latitude coordinate in decimal degrees. (It is positive because it is located north of the equator.)
- **UID** is a unique ID field for each facility.

Step 2

Right-click on the Demoland_Districts layer in the Layers Panel and select “Open Attribute Table.” This will open a table with the records of the attribute data associated with these areas.



	Region	Country	Dist_name	Shape_Leng	Shape_Area
1	Animal	Demoland	Bird	1.83118568670	0.22013876474
2	Animal	Demoland	Dog	1.27426242972	0.09105073327
3	Food	Demoland	Fruit	2.17146433984	0.20418907327
4	Animal	Demoland	Insect	1.39186442053	0.12293845320
5	Food	Demoland	Vegetable	2.66573720477	0.25022374471
6	Animal	Demoland	Fish	2.14836292349	0.18561623019

In this table, the important field to note is the following:

- **Dist_name:** Each district on the map must have a unique name. (NOTE: If this is not the case, then the table needs to be edited as such, i.e. Bird1 and Bird2, or Animal_Bird and Food_Bird).

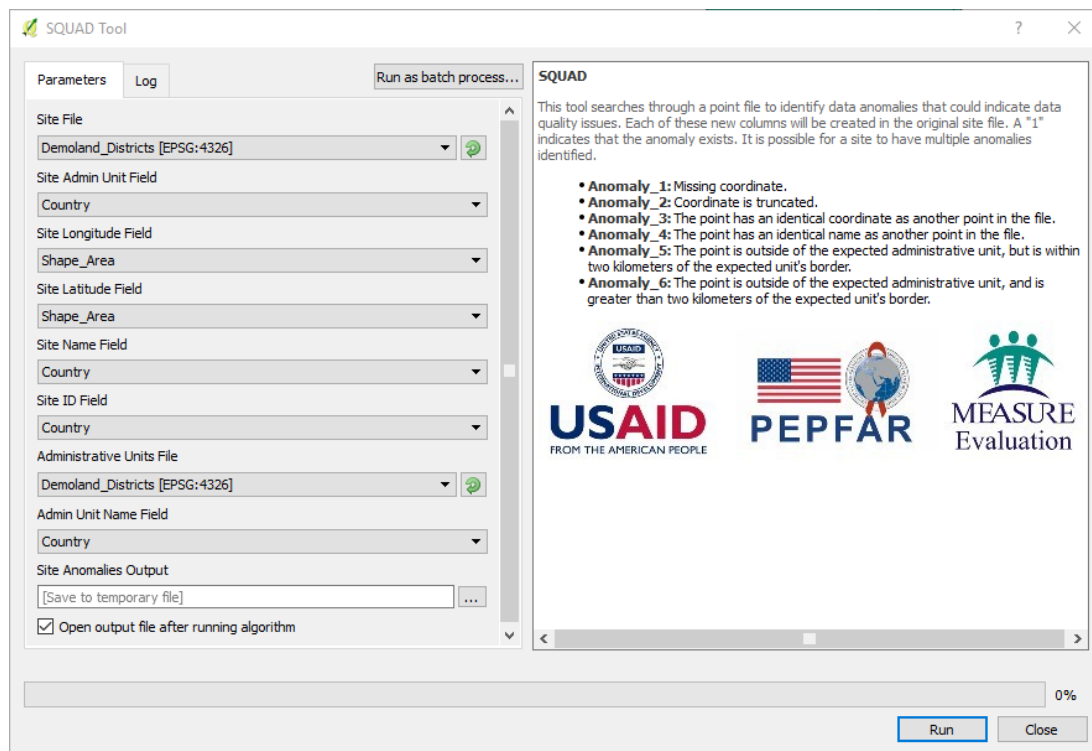
Running the Tool

Step 1

Click on the SQUAD tool





icon to activate the tool. The following dialog box will appear:



Step 2

Select the parameters needed to check for anomalies in the data set. For the Demoland test data set, choose the following parameters:

Site File	Demoland_facilities [EPSG:4326]	
Site Admin Unit Field	District	
Site Longitude Field	POINT_X	
Site Latitude Field	POINT_Y	
Site Name Field	NAME	
Site ID Field	UID	
Administrative Units File	Demoland_Districts [EPSG:4326]	
Admin Unit Name Field	Dist_name	

Explanation of Parameters

“Site File” is the facilities (point) file.

“Site Admin Unit Field” is the field that identifies the administrative unit to check for the facilities. In this example, “District” is the administrative unit.

The “Site Longitude Field” and “Site Latitude Field” show the coordinates in the facilities file. NOTE: These must occur in the “decimal degrees” format.

The “Site Name Field” displays the name of each facility, and the “Site ID Field” contains an ID for each facility.

The “Administrative Units File” contains the district polygons.

The “Admin Unit Name Field” contains the names of the administrative units to use for comparison with the field used in the facilities file. NOTE: These names must use the same spelling conventions as the names used for the “Site Admin Unit Field.”

Step 3

Click on the three dots beside the “Site Anomalies Output” box and **select** “Save to file...” to choose a name and location for your output file. Keep the “Open output file after running algorithm” box **checked**.

Site Anomalies Output

Z:/Demoland_anomalies.shp

☒ Open output file after running algorithm

Step 4

Review your entries, and then **click** on the Run button. The progress bar at the bottom will show you the progress as the program runs. The demonstration file is small, so the program should run quickly.

Observing the Results

Step 1

Open the Site Anomalies Output attribute table. (Hint: **Right-click** on its name in the Layers Panel to find the correct command.) The tool has added six new fields to the table.

Step 2

Click on the title bar of the **Anomaly_1** field a few times to sort it. When the table has been sorted based on that field, all the 1s will appear at the top of the table.

Site Anomalies Output :: Features total: 80, filtered: 80, selected: 0

	NAME	Region	Country	POINT_X	POINT_Y	District	UID	Anomaly_1	Anomaly_2	Anc
1	Cardinal	Animal	Demoland	0.0000000000	31.00729348090	Bird	942843dc4a91	1		
2	Strawberry	Food	Demoland	0.0000000000	30.49591018060	Fruit	ff186dbb53d4	1		
3	Ravioli	Food	Demoland	0.0000000000	0.0000000000	Dinner	d893a9d8c823	1		
4	Robin	Animal	Demoland	-44.89533611730	30.86118355340	Bird	dc6cba704964			
5	Hawk	Animal	Demoland	-45.01422905090	30.81785074000	Bird	437ef5aa687a			
6	Pigeon	Animal	Demoland	-44.70000000000	31.13618070930	Bird	8e52d1290c31			1

Show All Features

Look at each of these records. For the “Cardinal” facility, the POINT_X field is zero. For the “Ravioli” facility, both the POINT_X and POINT_Y fields are zero, (displayed here as “0.000000000”—depending on your settings, you may see <NULL> in these fields, or the fields may be blank. Anomaly_1 is the field for missing coordinates. These missing items need to be reviewed.

Step 3

Click on the rest of the anomaly title bars, sorting them to bring the entries coded with a “1” to the top. Can you determine what the problems might be for these records? (Remember, Anomaly 2 indicates truncated coordinates, Anomaly 3 indicates duplicate locations, and Anomaly 4 indicates duplicate facility names.)

Step 4

Anomalies 5 and 6 both apply to locations (according to the given coordinates) not falling into their expected districts.

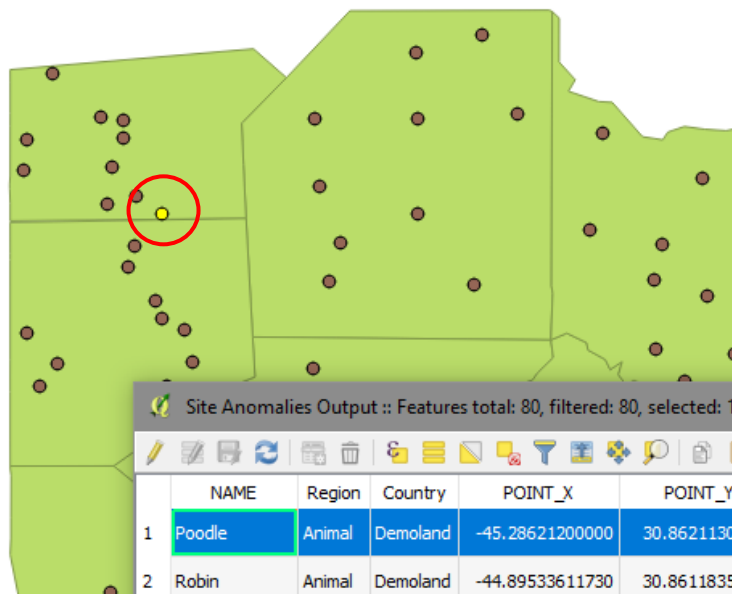
To examine Anomaly 5 on the map, **click** on the field name and sort it. Then **click** on the small box to the left of the record with a “1” code in the table to select (highlight) that record.

Site Anomalies Output :: Features total: 80, filtered: 80, selected: 1

	NAME	Region	Country	POINT_X	POINT_Y	District	UID	Anomaly_4	Anomaly_5	Anomaly_6
1	Poodle	Animal	Demoland	-45.28621200000	30.86211300000	Insect	73e3a13c4f29		1	
2	Robin	Animal	Demoland	-44.89533611730	30.86118355340	Bird	dc6ba704964			
3	Hawk	Animal	Demoland	-45.01422905090	30.81785074000	Bird	437ef5aa687a			
4	Pigeon	Animal	Demoland	-44.70000000000	31.13618070930	Bird	8e52d1290c31			
5	Woodpecker	Animal	Demoland	-44.74283078150	31.00000000000	Bird	4c2c62e984ee			
6	Crow	Animal	Demoland	-45.04645066750	30.90451645490		7c55d0a02f16			1
7	Parrot	Animal	Demoland	-44.81005638280	30.75396183680	Bird	60bd9e0f0e34			

Show All Features

Drag the table to the side of the map underneath to see that point highlighted on the map.





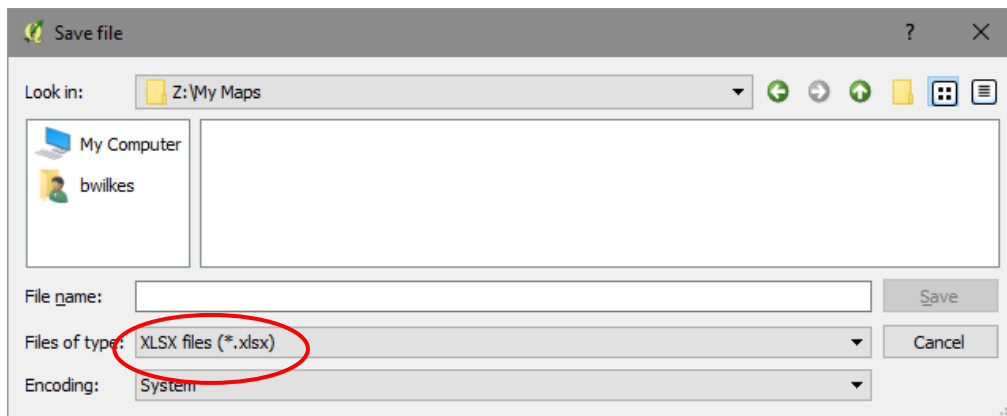
Do this for the points that have 1s marked for Anomaly 5 and for Anomaly 6. **What is the difference?** (Hint: The Anomaly 5 point is very close to a border.) What do you think is wrong with the Anomaly 6 points? (Hint: To determine whether a point is falling in the correct district, try **labeling** the districts with their names. To do this, **right-click** on Demoland_Districts in the Layers Panel and then **select** Properties. Then **select** the “Labels” tab. At the top of the box, **select** “Show labels for this layer” and Label with “Dist_name” and **click** on OK. Highlight the “Pear” facility in the Health_facilities attribute table. In which district should it supposedly be? Do you see the possible error?)

Step 5 (optional)

Save the table with the anomalies to Excel.

There are **two options** for saving the output to Excel:

1. If you have already chosen to output to a shapefile, **right-click** on “Site Anomalies Output” in the Layers Panel and then choose “Save As...” Under Format, choose “Comma Separated Value (CSV)” and enter a file name/location using the Browse button, and then click on Save. You can then go to your desktop and open this file in Excel.
2. If you would like to run a new file, click on the SQUAD tool button. Fill out the appropriate parameters. Under “Site Anomalies Output,” click on the browse button. Choose  “Save File As...” and then in the dialog box, under “Files of type,” select “XLSX files,” and  run the tool. The output will appear in the Layers Panel.



DATA CORRECTION PROCESS

When you begin the data correction process, here are some suggestions for handling the different types of anomalies.

Anomaly 1. Missing coordinates

- Review the data collection sheet, if available, and determine whether records were omitted.
- Obtain the actual coordinates of a facility using a handheld GPS receiver or mobile phone. For more information on GPS data collection, see the following resources:
 - MEASURE Evaluation's mini-tutorials (5- to 10-minute videos) can help beginners collect GPS coordinates, download the data to a computer, and carry out other basic GIS tasks: <https://www.measureevaluation.org/resources/training/online-courses-and-resources/non-certificate-courses-and-mini-tutorials/gis-step-by-step-tutorials/>.
 - MEASURE Evaluation also offers information on collecting data using a GPS receiver: https://www.measureevaluation.org/resources/training/capacity-building-resources/geographic-information-systems-mapping-and-analysis-of-spatial-data/tools-tips/FS1383_GPScoordinates_Dec2013.pdf/view.
- Obtain the coordinates through a visual examination in Google Maps or Google Earth. For example, a cursor placed over a known nearby road intersection will display the coordinates in the lower right-hand corner of the screen. More information on using Google Maps to search locations is available at <http://support.google.com/maps/answer/3092445>.

Anomaly 2. Truncated coordinates (lack of adequate precision)

- Review the data collection sheet, if available, and determine whether records were incorrectly transferred or whether digits were left off or rounded.
- Obtain the actual coordinates of a facility using a handheld GPS receiver or mobile phone (see resource links above).
- Obtain the coordinates through a visual examination in Google Maps or Google Earth. For example, a cursor placed over a known nearby road intersection will display the coordinates in the lower right-hand corner of the screen (see resource the link above).

Anomaly 3. Duplicate coordinates for distinct records

- Determine whether the anomaly is really an error. It could be correct, such as in the case of a dispensary located at the same address as a hospital.

Anomaly 4. Duplicate key attributes

- Determine whether the anomaly is really an error. It could be correct, such as in the case of two clinics in different parts of the country having the same name.

Anomaly 5. Coordinate not located where expected, but falling within two kilometers of a border

- Review the data collection sheet, if available, to confirm coordinates.
- Obtain an administrative boundary file from a different source. A point falling very close to a boundary could indicate that the boundary itself is wrong or inaccurate. A good source is the Database of Global Administrative Areas: <http://www.gadm.org/>.
- Validate coordinates using imagery such as Google Earth or Bing.
 - For information about adding imagery from within QGIS see <https://gis.stackexchange.com/questions/20191/adding-basemaps-from-google-or-bing-in-qgis> (this post talks about the OpenLayers Plugin for 2.18 and the XYZ Tile Server provider for 3.0).
 - For information about Google Earth, see <http://www.google.com/earth/>.

Anomaly 6. Coordinate not located anywhere near where expected

- Review the data collection sheet, if available, to confirm coordinates.
- Check the spelling of administrative units in the administrative boundary file.
- Check to confirm that the point file has the correct administrative area designations.
- Validate the coordinates using imagery such as Google Earth (see above), or re-collect the data using a GPS receiver or mobile device.


CONCLUSION

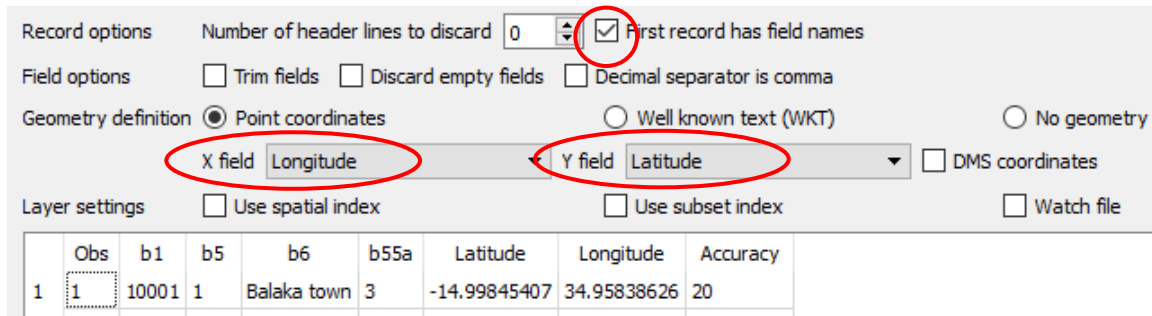
The SQUAD tool is useful for assessing the quality of a spatial database and does not require extensive GIS experience to run. The scenario described provides a hands-on exercise in running the tool and the types of potential errors that may be revealed. The anomalies provide a quick view of the scope of problems in a given file. Low numbers of anomalies indicate that the quality of the spatial data is good overall.

APPENDIX A. CREATING A POINT FILE FROM A LIST OF COORDINATES

The Spatial Quality and Anomalies Diagnosis (SQUAD) tool requires all inputs to be in the form of shapefiles. If you are starting from a spreadsheet that lists coordinate locations, you can plot these using QGIS and then export the result to a shapefile that contains the geometry and attributes for all the point locations.

The basic steps are as follows:

1. **Open** your spreadsheet in a program such as Excel and **save** it as a comma-separated values (CSV) file. This assumes that your spreadsheet contains separate columns for the X (longitude) and Y (latitude) coordinate values, and that the values are in decimal degrees format, stored with a precision of at least five decimal places. If this is not the case, you will have to format these values in Excel or another program before proceeding.
2. **Open** QGIS and **click** on the Add Delimited Text Layer  button. **Browse** to the CSV file and **click** on Open. Under File format, choose CSV. If the first record in your table contains field names, check that box.
3. Specify the Geometry definition (Point coordinates) and the X field (Longitude) and Y field (Latitude).

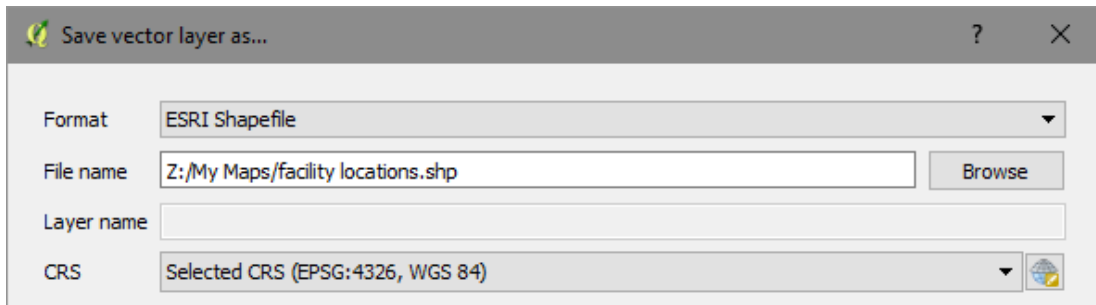


	Obs	b1	b5	b6	b55a	Latitude	Longitude	Accuracy
1	1	10001	1	Balaka town	3	-14.99845407	34.95838626	20

NOTE: In QGIS 3.0, choosing “Layer>Add Layer>Add Delimited Text Layer...” will take you to the Data Source Manager and the Delimited Text tab. From there, follow the steps above, choosing the CSV file format, specifying whether the first record has field names under Record and fields options and specifying the X and Y fields under Geometry definition.

4. **Click on OK.** The points should plot on the map, and a temporary layer will appear in the Layers Panel. Next you will save the file as a shapefile.

5. **Right-click** on the new temporary file in the Layers Panel and choose Save As... Under Format, choose “ESRI Shapefile.” **Browse** to a location and name it, and make sure the “Add saved file to map” box is checked. Then click on **OK**.



6. The resulting shapefile contains the X, Y locations. This file can be used with the SQUAD tool.

APPENDIX B. FREQUENTLY ASKED QUESTIONS ABOUT COORDINATE SYSTEMS AND PROJECTIONS

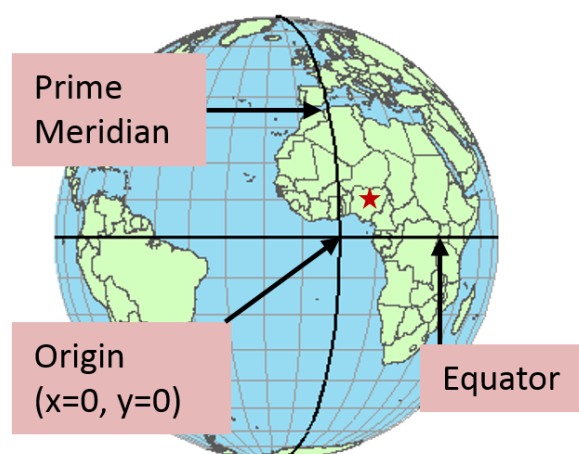
What is a projection?

There are two main ways to refer to coordinate locations on the Earth.

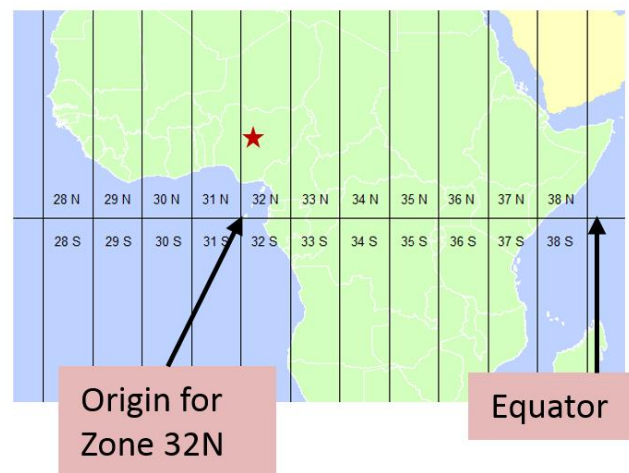
“Unprojected” coordinates refer to a point on the globe (sphere). For this system, coordinates are measured in **degrees**: 0 to 90 degrees north or south of the equator is the latitude; 0 to 180 degrees east or west of the prime meridian is the longitude. These can be further specified as degrees, minutes, and seconds (DMS) or as **decimal degrees** (DD). There are many conversion programs online to convert from DMS to DD.

“Projected coordinates” are projected onto a flat surface, such as a map. These are also called Cartesian coordinates. These are the X, Y coordinates used in algebra and on graphs. In a Universal Transverse Mercator (UTM) projection system, the Earth has been projected onto a flat surface and portioned into **zones**. Each zone has an origin, or 0,0 starting point, in its lower-left corner. Each set of coordinates is measured in **meters** from the zone’s origin.

For comparison, here are illustrations of unprojected coordinates for Abuja, Nigeria (on the left) and projected (UTM) coordinates for the same location (on the right).



★ **Abuja, Nigeria:**
9.05129° N, 7.48482° E
or 9°03'07" N, 7°29'08" E



★ **Abuja, Nigeria:**
333500 E, 1001500 N, zone 32E

A more detailed and further illustrated explanation of coordinate systems and Earth geometry can be found at <http://kartoweb.itc.nl/geometrics/Coordinate%20systems/coordsys.html>.

How do I determine which UTM zone to use?

An explanation and map of zones can be found at http://www.maptools.com/tutorials/grid_zone_details or <http://geokov.com/education/utm.aspx>.

To determine a location's UTM zone, type in the name of the location and "UTM zone" in Google, and then double-check the findings with one of the above charts.

How do I determine what projection I am working with in QGIS?

To determine whether your data source has a defined coordinate system, right-click on the layer in the Layers Panel, and click on **Properties** to open the **Layer Properties** dialog box. Click on the **General** tab, and then look in the **Coordinate Reference System** box.

QGIS comes with tools for defining and changing coordinate systems. For more information, see the latest QGIS user guide at <https://docs.qgis.org/2.18/pdf/bg/QGIS-2.18-UserGuide-bg.pdf>.

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